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OBSERVATIONS  
ON THE  
ACTION OF CHLOROFORM

ON THE  
FUNCTIONS OF THE HUMAN BRAIN AND SPINAL  
CORD, AS WITNESSED IN EXTENSIVE INJURIES  
OF THE CRANIUM AND BRAIN.

*Read before the Southern Surgical and Gynæcological Association,  
at Charleston, S. C., November, 1894.*

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Observations on the Action of Chloro-  
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IN entering on this interesting and important subject, I am aware that I am engaging in a field of study and observation comparatively unexplored and unknown. The observations and investigations designed to be published to the world in this paper are based upon ocular demonstrations of the action of chloroform on the human brain, while exposed in extensive compound comminuted fractures of the cranium and laceration and injury of the membranes and brain-substance itself. Two most valuable and excellent opportunities have in the past come under my care and offered themselves for study and observation of this kind.

The first case of this kind which came under my care occurred in the year 1860, and was published in the October number of the *American Journal of the Medical Sciences*, and was extensively republished, but probably did not make the impression that it deserved because

of the excitement and turmoil of civil war that soon followed. The title of this paper was "A Case of Compound Comminuted Fracture of the Cranium, Severe Laceration and Destruction of the Brain, followed by Fungus Cerebri and terminating in Recovery."

The second case that occurred was that of a Confederate soldier in one of the great battles in Virginia.

In this case a ball or grape-shot as large as a hen's egg had entered the centre of the frontal bone or os frontis, penetrated the frontal lobes to the depth of an inch and a half, and had embedded itself in the cerebral substance and was tightly wedged in the frontal bone.

I will mention the fact here that in this case the ball was doubtless, for obvious reasons, a spent ball. The fractures in both of these cases were in the os frontis, and in both there was extensive injury and laceration of the frontal lobes of the brain and considerable loss of cerebral tissue. But, notwithstanding these extensive injuries of the organ in both, there was no loss whatever of consciousness or sensation.

In both cases the necessary surgical operations lasted over an hour, and, because of the acute sensibilities of the patients, the free use of chloroform was required during the entire operations and subsequent dressing of the wounds. In the first case the patient was brought under the anæsthetic compound of chloroform 3 parts, ether 1 part, as many as four different times, as the effects would pass off. In the second case the patient was placed under the effects of chloroform alone as many as three different times, so that the action of the exposed brain could be accu-



rately observed and studied, both when under the influence of chloroform and when without it. To enable us to comprehend clearly the action of chloroform on the human brain exposed to the naked vision and to form an idea of the conduct of the organ in a state of anæsthesia, I will here quote portions of the history of Case I. relating to this question.

In this case the fracture occurred in a colored boy from the kick of a newly shod horse, and occupied a large portion of the os frontis; the opening in the skull would have measured two inches horizontally and an inch and a half in width. The fractured bones were driven into the frontal lobes fully an inch or more, lacerating extensively the membranes and lobes, considerable portions of the destroyed brain-substance having been forced out on the surrounding skin. A large amount of blood had escaped and was still escaping from the wound.

Notwithstanding this extensive injury, the consciousness and sensibilities of the patient were so acute and his resistance so uncontrollable that anæsthesia was imperatively required.

Having no guide to govern myself and assistant in forming an opinion of the effects of this class of agents on a brain so dangerously injured, we discussed the probable results with caution and deliberation.

Up to that time there had been no case placed on record of the use of anæsthetics in extensive injury of the cranium and brain, and consequently no experience in their effects in such cases, and I am not aware, even at the present time, that any such case has been placed on record since. Fearing lest the pure chloroform might be too depressing, I determined to

use a combination consisting of chloroform 3 parts, ether 1 part, hoping that in some way the ether might counteract the depressing effects of the chloroform.

After the patient had been placed thoroughly under the influence of the anæsthetic, we found, on examination, that there was an opening in the os frontis two, or rather more than two, inches long, extending across the forehead, and one inch and a half wide, and the fractured bones corresponding to this opening had been driven back into the frontal lobes of the brain fully an inch in depth, lacerating the membranes and destroying the brain-substance to that extent. Ten or twelve pieces of bone, some two inches long, were removed, having been embedded in the brain, the loose portions of membrane cut away and removed, and then the lacerated and detached portions of brain-tissue, amounting to two tablespoonfuls, were carefully removed, and the wound, which was a ghastly one, was sponged out carefully with boiled water until all hemorrhage had ceased. Through this very extensive opening in the skull the brain could be seen perfectly exposed to view, and through it we could observe the physical action of the brain perfectly, both under the influence of chloroform and when free from it; and we could also observe its action under the influence of stimulants. There could not have been, under any circumstances, a more favorable opportunity to witness and deliberately observe the results of the action of chloroform on the functions of the human brain than this case afforded. On this large area of exposed brain we could see the effects of the anæsthetic plainly on the

rhythmic pulsations of the brain, also its wonderful effects on the arterial tension and circulation of that organ, and, finally, on the cerebral hemorrhage.

On the peculiar action of chloroform on the human brain, whether this agent tended to diminish or increase its circulation, whether it produced a state of anæmia or congestion of that organ, was, in the professional opinion, an unsettled question. The facts in this case, I think, settle this question definitely. We observed that the first perceptible effect of the anæsthetic on the action of the brain was, when under full anæsthesia, a marked and sudden diminution of hemorrhage, which previously had been free; then, when the anæsthetic influence subsided, there was return of active hemorrhage. This fact indicated to us that the action of chloroform was to lessen and reduce the cerebral circulation beyond a doubt, and when the wound had been cleaned of all *débris* of fractured bone, membranes, and lacerated brain, this supposition proved to be correct. The operation was in progress about one and a quarter hours, and during that time the patient was placed under the anæsthetic four different times, as the effects would subside. On these occasions, whenever the patient was fully under the effects of the anæsthetic, then the hemorrhage would subside, the rhythmic pulsations of the brain would cease, the exposed surface of the brain would lose its florid complexion and assume a decidedly pale and ashy appearance, and at the same time the respiration would become slow, the impulse of the heart become feeble, and the extremities rather cool and the pupil contracted.



On the contrary, when the effects of anæsthesia would begin to subside, then hemorrhage, at first slowly, would begin to return, the cerebral pulsations begin to reappear, and the organ would again assume a florid appearance, with indications of returning turgescence.

When the patient was fully under the influence of chloroform the circulating volume of blood in the brain became perceptibly reduced. On the contrary, when the effects of the anæsthetic passed off, the normal amount of blood returned to the brain, as indicated by the change from its pallid complexion to the florid appearance of congestion. These peculiar phenomena recurred as many as four different times in this case during the operation, and would indicate that death from chloroform does not result from congestion, but from anæmia of the brain.

*The Combined Action of Chloroform on the Cerebral Pulsations and the Function of Respiration.*—What connection has the function of respiration with the state of the cerebral pulsations? is a question not devoid of interest. In this, the first case, it was observed that whenever the pulsations of the brain were full, were of a heaving, impulsive character, the respiratory act was correspondingly full, deep, and complete. But as soon as these pulsations showed an indication to diminish in force under the action of chloroform, the respiratory act became slower, less deep and complete. These peculiar indications were so plain and perceptible as to attract our attention.

*Effects of Struggling or Muscular Exertion or Mental Excitement on the Brain of the Patient while inhaling Chloroform.*—The effects



of these influences on the functions of the brain were positive and decided. Any struggling, attempt at resistance, unusual muscular exertion, or mental excitement produced marked and sudden, even violent, change in the cerebral circulation. In this case, after the wound was cleaned and the patient had regained consciousness, it became necessary again to resort to anæsthesia to insert the numerous sutures ; the patient became violently excited and gave energetic resistance to our efforts to chloroform him. Immediately the hemorrhage returned, the cerebral pulsations became violent, and the brain intensely congested until complete anæsthesia was accomplished, when the excited organ became perfectly quiet, pale, and all hemorrhage ceased. Under the effects of mental excitement and muscular exertion, the cerebral pulsations became not only forcible, but exceedingly irregular, and there was always irregularity of the respiratory and cardiac action in corresponding degree. These facts teach us an important lesson in the administration of anæsthetics, and that is, to avoid, if possible, any mental excitement or physical exertion of the patient while undergoing anæsthesia, for the purpose of preventing violent and unusual changes in the circulation both of the brain and medulla oblongata, the centre of respiration. At this critical moment, when the system is on the verge of passing from a state of consciousness to one of profound insensibility, any violent excitement or sudden increase of the cerebral circulation or any considerable irregularity might give rise to a corresponding depression of circulation and produce fatal consequences. This important fact in regard

to the effects of struggling or resistance on the circulation of the brain indicates to us very positively the necessity of using gentleness, caution, moderation, and the avoidance of force in the administration of chloroform. In this way all shock to the brain and centre of respiration may be avoided.

CASE II.—This case was that of a Confederate soldier who was brought into my field hospital during one of the great battles near Richmond, Va. A spent grape-shot as large as a hen's egg had embedded itself into the os frontis and to the extent of an inch and a quarter into the frontal lobes. The patient was perfectly conscious, sensible, and possessed perfect control over the muscular system. The ball was wedged tightly in the skull, and for its successful removal it was necessary to trephine a ledge of bone to enable us to use the elevator to force it out, and as the wounded man requested chloroform preliminary to the operation, he was placed thoroughly under the anæsthetic. I will state here that no ether was used, to my knowledge, in the Confederate army. After the removal of two semicircular pieces of bone, the elevator was passed underneath the ball and it was pried out, leaving a wound in the frontal lobes an inch and a quarter in depth, with all the fractured bones driven into the brain, lacerating that organ extensively. Under the action of the chloroform the hemorrhage had ceased and the cerebral pulsations were nearly suspended. After the wound was cleansed of all fractured bones, lacerated brain, and membranes, we had a wound two inches in diameter and an inch and a half in depth. Up to this stage of the operation the patient had

been under the anæsthetic twice, and at each time the cerebral pulsations were very nearly suppressed, the hemorrhage ceased, and the surface of the exposed brain became pallid. On the contrary, when the effects of the anæsthetic passed off, the regular rhythmic pulsations would return, the hemorrhage be renewed, and the brain become florid. When beginning the administration of the anæsthetic, any struggling of the patient was certain to give rise to increased pulsation and activity of the cerebral circulation and symptoms of congestion, until unconsciousness ensued, when the same pallor of the brain and subsidence of rhythmic action and all hemorrhage invariably followed. These peculiar results invariably followed the action of chloroform in the second as well as in the first case. In this case the chloroform was administered as many as three times, and in every instance the results were identical in effect and in order.

The history of this case cannot be regarded in any other light than as a complete confirmation of the facts elicited in the first case: that the action of chloroform exerts a potent influence on the circulation of the brain; that it is not an excitant of that organ, and that it does not produce congestion of its circulation or even an increase; that it reduces cerebral circulation and its rhythmic movements; that it controls hemorrhage; and, finally, to be more definite, that it can reduce the circulation of the brain from twenty to thirty per cent., and while that state of anæsthesia continues, a temporary state of anæmia, not only of the brain itself, but of the medulla oblongata and spinal cord to a limited extent, results.



It would appear that it requires a longer time and a larger amount of chloroform to produce a serious degree of anæmia of the medulla than of the cortex of the brain, as the anæsthetic influence is primarily on the cortex and secondarily on the medulla. An absolute state of anæmia of the medulla would insure certain death from suspension of respiration. It is highly probable that ether acts differently on the brain; that it produces a state of venous congestion similar to that of alcohol, when taken internally.

The positive and unmistakable evidence in both of these cases goes to establish the fact that the anæsthetic action of chloroform on the human brain and cerebral anæmia are invariable accompaniments in the relation of cause and effect. It will be observed, in the two cases reported, that during the surgical operations performed, the first patient was subjected to the influence of chloroform four times and the other three times. At each administration, from the time that the anæsthetic influence began, the circulation in the brain began to diminish, the hemorrhage and pulsations to decrease, until, under full anæsthesia, complete anæmia ensued.

*Effects of Alcoholic Stimulants on the Brain when under Chloroform Narcosis.*—This would appear to be a favorable stage to allude to the results of observations on the action of stimulants on the human brain when under chloroform narcosis, as witnessed in the cases reported, as I had a favorable opportunity on these occasions to witness both the conduct of the brain under simple chloroform and under both chloroform and whiskey.

At one period during these tedious operations, both lasting an hour or more, the patient showed indications of failing respiration and cardiac action, when it became necessary to resort to stimulants. Both patients were in a profound state of narcosis, and consequently they could not be given by the mouth, and at that time the hypodermic syringe was unknown, hence they were given per rectum. The indications during this profound state of narcosis were almost entire suspension of cerebral pulsations, extreme pallor of the brain, entire cessation of hemorrhage, slow, shallow respiration, and feeble pulse. In the case of the boy, an ounce of diluted whiskey was injected into the rectum. In fifteen minutes the brain began to respond, feeble pulsations beginning, slight return of hemorrhage, and then the circulation in the brain became more active and the organ lost its extreme pallor, the respiration was regular and deeper, the pulse fuller, more regular, and stronger, until there were assurances of reaction, when the operation was continued. In this case there was no necessity of resorting again to the use of stimulants.

In the case of the wounded soldier, there were two occasions of rather alarming depression from chloroform narcosis during the operation, which lasted an hour and a quarter, when it became necessary to resort to stimulation.

The hemorrhage in this case, while the patient was under the profound influence of chloroform, was observed to suddenly cease, the brain to become pallid, the pulsations to be almost entirely suspended, the respiration to be very feeble, slow, and shallow, and the

heart to show indications of failure. 2 ounces of diluted whiskey were promptly injected into the rectum. In fifteen or twenty minutes the heart began to respond, the respiration to improve, the hemorrhage from the brain to return, and the complexion of the organ to become more florid, and then renewal of pulsation. I am satisfied that in each of these instances of threatened collapse the primary action of the alcohol was on the heart. Previous to a return of blood to the brain, of hemorrhage, of pulsation, or of increase of respiratory action there was increased action of the heart, the pulse becoming fuller, stronger, and more regular. Relative to the action of alcohol on a patient when under the influence of chloroform, and more especially on the functions of the brain under these circumstances, the results of the administration of stimulants in these two cases, while in a state of chloroform narcosis bordering on collapse, indicate, in a manner beyond a doubt, that stimulants given in this condition exert a powerful, exciting, and energizing effect, first on the heart, then on the circulation in the brain and medulla, and as soon as the medulla—the centre of respiration—is touched by the alcoholic stimulant, the function of respiration begins also to respond.

In the process of restoration from chloroform-poisoning, when stimulants are resorted to, that their primary action is on the heart before the stimulating influence reaches the brain I have not only the facts in these two cases to show, but also facts derived from cases of true chloroform collapse.

In a case of this kind, of a female who secluded herself in a room and began inhaling



from a six-ounce bottle of chloroform, to relieve neuralgia, she was found in a profound state of collapse, the bottle turned upside down, the bedding saturated, the pulse and respiration had ceased, the sounds of the heart absent, the pupils dilated, temperature  $95^{\circ}$  F. In the process of resuscitation, 4 ounces of whiskey were injected hypodermically, the head was lowered below the level of the body, nearly a half-grain of strychnine in all was also injected, and artificial respiration resorted to. But the first to respond to these powerful stimulants was the heart, then the respiration, then, in turn, the function of sensation to the hypodermic needle, and, lastly, consciousness.

The result of personal experience in the use of stimulants in chloroform narcosis, I think, will bear me out in the assertion that the combined action of alcohol and strychnine is better than either alone. A large quantity of whiskey given in chloroform collapse possibly might tend to increase the relaxation of the heart; but when given in connection with strychnine, this tendency is corrected. I feel satisfied that when stimulants are given, either before or during chloroform narcosis, they should always be given in connection with strychnine, as this combination affords the most potent excitants of the centres of respiration, circulation, and consciousness that we possess.

In regard to the propriety and advantage of resorting to stimulants in chloroform-poisoning, the evidences elicited in the two original cases reported would seem to establish the fact that they act as potent energizers of the centres of respiration, circulation, and consciousness.

*Cerebral Anæmia caused by the Action of Chloroform in its Relations to the Functions of Respiration, Circulation, and Heat Generation.*

—The diverse influence exerted by the opposite conditions cerebral anæmia and cerebral plethora on the functions of respiration, circulation, and heat generation were among the most interesting phenomena witnessed in the history of the two cases cited. While under chloroform, as the cerebral anæmia increased, there was observed a simultaneous decline in the functions of respiration, of circulation, and then in heat generation, and this decline steadily progressed until the anæsthesia was complete and cerebral anæmia reached its lowest stage, or, in other words, until the reduction of circulation of the brain was lowered to a point where all hemorrhage ceased, the brain had lost its florid complexion and had assumed a pallid hue, and nearly all pulsation had been suspended. When the cerebral anæmia had reached this point, the respiration was manifestly reduced in frequency and force, the cardiac action became slow, arterial tension markedly reduced, and correspondingly there was reduction of heat generation. On the contrary, as this cerebral anæmia passed off when the anæsthetic was suspended, there was return in force and depth of respiration, in arterial tension, and in cardiac force and heat generation.

The action of chloroform on the human system must be regarded in the light of a complex action, and not, as too many regard it, as a simple one. Cerebral anæmia and abolition of the faculty of consciousness and the function of sensation absolutely go hand in hand ; they

begin, progress, and terminate simultaneously. Then, when anæsthesia is pushed still further, anæmia of the medulla and spinal cord commences, and, as it progresses, the vital functions of respiration, reflex action, circulation, and heat generation succumb, until, when the anæmic condition of the brain reaches a point where there is not sufficient arterial blood furnished the brain and medulla to sustain vital action, then the respiratory centre begins first to indicate signs of failure; then follows paresis of the vaso-motor or circulatory centres, and, finally, all reflex action.

It would appear that in this process of suspension of the vital functions from chloroform narcosis the various centres succumb in the following order: first, consciousness and sensation; the next in order is that of respiration; then circulation; lastly, the entire functions of the spinal cord and reflex action. When the action of chloroform is confined to the brain alone, it may be in a state of profound narcosis for hours, with impunity, provided anæsthesia goes no further; but we must not encroach upon the medulla to any serious extent, or we promptly suspend respiration. We can, with impunity, continue a state of anæmia of the cortex of the brain, the centre of consciousness, for a considerable length of time, wherein the circulation of the brain is reduced from twenty-five to thirty per cent. We often see this state of affairs exemplified in cases of syncope, which is a harmless condition; but we cannot carry chloroform narcosis to that point, when the circulation in the medulla and the vaso-motor centres is diminished thirty or forty per cent., without producing paresis of



those organs and suspension of their functions.

In regard to the quantity of chloroform required to reduce the circulation of the brain to a point compatible with the anæsthetic state, there is a marked difference in different individuals. In the first case reported, that of the boy of nineteen, 1 drachm of the chloroform and ether mixture produced profound anæsthesia; while in the second case, that of the adult, it required 3 or 4 drachms to produce a state of anæmia of the brain and unconsciousness. The less difficult it was to effect this anæmic state of the cerebral circulation the more readily was anæsthesia accomplished. On the contrary, when the circulation of the brain was excited by any cause whatever, and its action and arterial tension elevated from mental excitement, from muscular exertion, as violent struggling or resistance, it required a much larger quantity of the anæsthetic and a longer time to induce cerebral anæmia, and consequently anæsthesia. In both of these cases reported it may be stated as a fact based on incontestable evidence, that in no instance, in all these administrations of chloroform, was the patient brought to a state of anæsthesia without the preliminary cerebral anæmia, and in no case could anæsthesia be effected while the circulation of the brain was active and vigorous.

*The Safety of Anæsthesia in Operations for Injuries of the Cranium and Brain.*—There is a certain class of injuries of the cranium and brain where it may become necessary to resort to anæsthesia, either to control the patient or to save him from unnecessary suffering. Probably

the great majority of such patients do not require it because they are already in a state of coma ; then it can apply only to that class in which consciousness is either wholly or partially retained.

We have seen that the action of chloroform on the brain is to reduce its circulation from twenty to thirty per cent. and to arrest cerebral hemorrhage. These facts are to constitute our guide in the application of the agent in any given case. In our operations in such cases it is desirable to produce unconsciousness and insensibility, and at the same time to reduce the momentum and quantity of the cerebral circulation and to arrest excessive hemorrhage without impairing respiration. For instance, in cases of injury of the brain where the patient, though in a state of semi-consciousness, is restless, struggles against all interference, and resists treatment ; in cases of delirium or great mental or nervous excitement ; and when the hemorrhage is copious, even though in a semi-comatose state, chloroform is admissible. It not only quiets nervous excitement, but reduces cerebral congestion and engorgement and saves the loss of blood. On the contrary, in cases of injury of the brain or of other portions of the body, accompanied with excessive shock and depression of the circulation and reduction of blood-supply, the brain is already in a state of anæmia, and to reduce its circulation still further would be, in all probability, to destroy the life of the patient.

Suppose, for instance, a case of this kind. We are called to operate upon a patient who has received a severe injury and is laboring under a tremendous shock, and the blood-sup-

ply to his brain, from shock or hemorrhage, has been reduced forty or fifty per cent. Would it be justifiable under such circumstances to give an agent, as chloroform, which will reduce the cerebral circulation at least twenty per cent. more? Yet this very result does actually occur when we give chloroform, when the circulation of the brain is reduced forty or fifty per cent. from shock or hemorrhage. We can calculate very accurately—I may say to a certainty—that chloroform is capable of reducing the cerebral circulation from thirty to forty per cent., and possibly more; hence we have in this fact a valuable guide in giving chloroform in shock. If we could all have the rare opportunity of observing a human brain exposed through a large open window in the skull, with every action and every change in its circulation and rhythmic movements exposed to view, we could see, under the action of chloroform, the pulsations of the organ grow fainter and fainter and more and more feeble, until they were reduced to a mere tremor, and finally ceased almost entirely. In the mean time the surface of the organ is losing the turgid, florid appearance, is growing paler and paler, and actually appears to diminish in volume. We know by these indications that the volume of blood circulating in the brain has been reduced to the border lines of danger; and it can be stated with certainty that in every case where anæsthesia from chloroform is produced, these wonderful and interesting changes are in actual progress in the brain. In my personal observations of the action of chloroform in these cases on the functions of the brain, I found a remarkable correspondence between that ashy pallor of the



lips and prolabia peculiar as an initiatory symptom of chloroform collapse and that same corresponding ashy pallor of the surface of the brain from the same cause. In threatened collapse, deadly pallor of the brain appeared invariably in unison with an ashy hue of the lips; these peculiar indications appeared in both cases. Thus, in the peculiar extreme deadly pallor of the lips and prolabia we have a very correct and certain index of the true condition of the cerebral circulation.

*Relationship of the Degree of Arterial Tension in the Pulse and Brain to the Respiratory Capacity.*—In a state of anæsthesia in all cases there is diminution of a certain per cent. in the capacity of the lungs for inhalation. Probably in a slight degree the respiratory centre is affected in all cases of profound anæsthesia, and the capacity of the lungs for inhalation reduced in corresponding degree. Probably five or ten per cent. less of air is inhaled in every case of anæsthesia, but when it reaches twenty or thirty per cent., then we are approaching a state of asphyxia. During the operation in the second case reported, there were two occasions in which respiratory failure was threatened, and on both of these occasions there was marked decline in the arterial tension in the brain and pulse, and when the lungs were tested by auscultation, it was found that atmospheric air did not reach the bases at all, causing a probable reduction in inhalation of twenty per cent. On the contrary, when the arterial tension in the pulse and brain was restored, the respiratory capacity increased to within ninety-five per cent. of the normal. As observed in this case, the rise and fall of arterial tension in the

pulse and brain and the respiratory capacity correspond in precise ratio. These facts would go to indicate that accurate and perfect consonance of action of the respiratory and circulatory centres exist in chloroform narcosis.

In the decline and failure of arterial tension in the brain and pulse there invariably is associated with the condition *shallowness* of respiration, so much and so justly dreaded by all surgeons and anæsthetists. The diaphragm acts irregularly and spasmodically, and the noise made by the effort at inhalation somewhat resembles hiccough, while the intercostals do not elevate the ribs sufficiently to expand the chest to the entrance of air. The respiratory and circulatory centres are so intimately associated and so thoroughly co-operative in their action that one of these vital functions cannot be seriously impaired without affecting the other. A sudden and decided reduction in arterial tension cannot occur without reducing in corresponding degree the respiratory capacity. Neither can the respiratory capacity be reduced to any serious extent without affecting arterial tension. I saw this peculiar phenomenon most clearly illustrated in the second case. If we desire to prevent untoward results in the administration of chloroform, we must watch with unrelenting vigilance the state of the two great vital functions,—circulation and respiration; and in case of collapse, devote our attention assiduously, not to one alone of the functions, but to both equally. A revival of arterial tension in the pulse indicates its revival in the brain, and a revival of respiratory action is almost certain to be followed by a restoration of arterial ten-

sion. When we have secured a state of unconsciousness and insensibility, we have an infallible indication that the arterial tension of the brain is reduced to the point of safety. When we carry it still further and reduce the inspiratory capacity of the chest or act of respiration to two-thirds of the normal standard, we have an equally infallible sign that the arterial tension and circulation of the medulla are being reduced to a state of anæmia dangerous to life. But this wonderful property of chloroform to reduce arterial tension and circulation in the brain and spinal cord gives to it a decided advantage as a remedy in congestions and convulsive diseases of these organs.

*The Action of Chloroform in Active Congestions and Engorgements, Violent Convulsive Movements, and Maniacal Excitement of the Brain.*—I trust that I have been enabled to show you the wonderful power of chloroform to reduce not only arterial tension in the brain, but its power to actually reduce the circulating volume of blood in that organ; this must be regarded as a most important fact. We all know and appreciate the power of chloroform in violent convulsive affections with high arterial tension and an abnormal amount of blood in the brain. Nothing that we possess is capable of reducing arterial tension and cerebral congestion so speedily and easily; and I am impressed with the belief that in those cases of violent convulsive movement, maniacal excitement, high arterial excitement, and congestion there is no remedy whose action we can gauge so accurately as chloroform. If we find that the tension of the pulse is reduced thirty per cent., we may be certain that there has been a

reduction in the arterial tension and circulation of the brain to that extent.

Many years ago, in a remarkable case of cerebral hemorrhage in the left hemisphere of the brain, resulting in paralysis of the opposite side, congestion, and finally inflammation of that hemisphere, with great restlessness and maniacal excitement, there was a high degree of arterial tension. But one of the most peculiar features of the case was an incessant involuntary rotary motion of the left arm that could not be controlled by the combined exertions of three or four men. In thirty minutes' time the free administration of chloroform would reduce this arterial tension fifty per cent., would arrest this rotary motion of the arm, and produce quiet sleep, indicating an equal reduction of arterial tension and circulation in the brain, and invariably after recovery from the effects of chloroform the patient would become more conscious, though he ultimately died of inflammatory softening.

It is thus clearly to be seen that in those cases of active delirium, maniacal excitement, or convulsive movement attending injuries of the brain, accompanied with a high arterial tension, symptoms of congestion, and even inflammatory action, when such a pathological combination does occur, it is not only no bar to the administration of chloroform, but is a condition actually favorable to its action. In congestion of the brain, whether traumatic or idiopathic, if coma is absent, if sensation is present, even if the patient is in a semi-conscious state, with active congestion, if necessary, chloroform is entirely admissible, as it will accomplish what depletion cannot do



and that is, to reduce the circulation of the brain.

*Comparative Action of Chloroform and Ether on the Human Brain.*—I think that there can be no doubt that the action of chloroform on the circulation of the brain differs materially from that of ether; that the one causes a state of positive reduction and consequent anæmia, and the other not only does not diminish the cerebral circulation, but, on the contrary, rather produces a venous plethora of the organ. From the effects of ether we never have that marked reduction in the arterial tension, that pallor of countenance, and ashy color of the lips that we find in the anæsthesia of chloroform. On the contrary, under the influence of ether, we often find the face deeply congested. While it is true that I have not seen a brain exposed under the action of ether, as in the case of chloroform, yet all who habitually administer ether are aware of the fact that under its influence marked reduction of arterial tension is not a usual result. I believe that in this difference of physiological action of the two remedies lies the safety of ether over chloroform, that ether rarely, if ever, causes a dangerous degree of reduction of circulation in the brain and medulla. In cases attended with shock from injury, imperfect reaction, or great physical prostration, either from disease, or from constitutional or temporary causes, where a surgical operation becomes necessary and it becomes our duty to elect between the anæsthetic to be selected, I think the facts established by the history of the two cases reported would indicate clearly that under such circumstances ether is the appropriate anæsthetic. When the

circulatory tension, whether general or cerebral, is low, I would hesitate in the use of chloroform. On the contrary, when the cerebral circulation is good, when the circulatory tension is not below par, chloroform is not only safe, but free from some of the dangers of ether.

Chloroform, from the beginning of its true anæsthetic action, is a depressant of the circulatory tension of the brain, and continues to reduce arterial circulation in the brain until, when the agent is pushed to extremes, there is absolute collapse of cerebral circulation. On the contrary, the primary effect of ether on the circulation of the brain is that of a direct stimulant, which finally results, when profound anæsthesia takes place, in a state of partial venous congestion of that organ similar to a state of profound alcoholism.

In using ether alone we do not hazard that extreme and dangerous reduction of the circulation of the brain and consequent anæmia that follows the indiscreet and careless use of chloroform as an anæsthetic.

If the conclusions arrived at from my observations on the action of chloroform on the human brain in the two cases reported be correct, and there can be no doubt of the facts elicited in these cases, then these facts go to prove that one of the chief, if not the chief, dangers in the use of chloroform is extreme reduction in the circulation of the brain and medulla, and also that the susceptibility to the influence of this remedy differs widely in different individuals,—so widely, indeed, that we cannot, without experiment in any given case, determine the degree of susceptibility. And, furthermore, that the only true security in ad-

ministering this agent consists in giving it in drop doses on a small pervious mask held over the nose and mouth, admitting sufficient atmospheric air for respiratory purposes.

In conclusion, I desire to state that after my first experience with my original case of injury of the brain in which chloroform was used, and its history in condensed form was published in the October number of the *American Journal of the Medical Sciences* in the year 1860, I was so much impressed with the importance of the facts elicited by the action of chloroform in that case that I was induced to collect all available information pertaining to this subject, with the view of preparing for publication at some future time a more elaborate paper on the action of chloroform on the human brain. The second case of injury of the brain which was adapted to the application of chloroform occurred in the year 1862, and has never been heretofore reported. This case, very fortunately, afforded me another and even better opportunity to test the effects of chloroform on the brain than the first.

While hoping to have other cases of the kind to add to the strength and interest of my report, none others of a similar kind and character to which chloroform was applicable have so far come under my observation. Of the two cases reported, very complete notes were taken soon after their occurrence, and these notes constitute the groundwork of the present paper.











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